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(54) Title: METHOD AND SYSTEM FOR ARCHIVING MEDICAL IMAGES

(57) Abstract: A method, and an associated system, for acquiring and archiving images of the body of a patient. The system includes an imaging device, such as an ultrasound probe, for acquiring the images; a tracker for measuring the position and orientation of the imaging device relative to a frame of reference; a memory for storing a map of a surface of the body relative to the frame of reference; and a display unit for displaying the images along with visual or textual indications of their positions and orientations relative to the body. Optionally, the system includes a stylus for digitizing the surface to provide the map; alternatively, the imaging device itself is used as a stylus. The system also includes a tracker for measuring the position and orientation of the patient, both as the map is digitized and as the images are acquired. As the images are acquired, they are annotated with respective indications of the corresponding positions and orientations of the imaging device relative to the body, to facilitate a subsequent medical procedure with reference to the images.

METHOD AND SYSTEM FOR ARCHIVING MEDICAL IMAGES

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to medical imaging and, more particularly, to a method and system for archiving images of a patient's body that are acquired freehand.

Medical procedures commonly are performed with reference to images of the patient's body. In many such procedures, the images are acquired interactively in the course of the performance of the medical procedure. See, for example, Ben-Haim et al., WO 97/29682, which describes the guiding of a biopsy needle to targeted tissue with the aid of ultrasound images.

Two prior art references of particular note in this context are Gilboa et al., WO 00/10456 and WO 00/16684, both of which documents are incorporated by reference for all purposes as if fully set forth herein. WO 00/10456 teaches intra-body navigation of a probe in conjunction with imaging by a C-mount fluoroscope. WO 00/16684 teaches the use of a representational imaging device, such as an ultrasound probe, in conjunction with the C-mount fluoroscope of WO 00/10456, for the purpose of identifying and recording points-of-interest, within the body of the patient, towards which the probe subsequently is navigated. Figure 1, which is adapted from Figure 2 of WO 00/16684, shows a patient **24** lying on an operation platform **34** and being imaged by a C-mount fluoroscope **22**. A catheter **26** is navigated within a body cavity **28** of patient **24**. This navigation is enabled by the provision of a transmitter **30** of electromagnetic radiation under platform **34**, a receiver **40** of electromagnetic radiation rigidly attached to fluoroscope **22**, and a receiver **32** of radiation rigidly attached to catheter **26**, all three of which are connected by wires **51** to a computer **50**. Fluoroscope **22** is used to acquire an image of a portion of the body of patient **24** that includes body cavity **28**. As explained in WO 00/10456, transmitter **30** defines a reference frame, and the signals received by computer **50** from receivers **40** and **32** in response to the electromagnetic radiation transmitted by transmitter **30** are indicative of the positions and orientations of fluoroscope **22** and catheter **26** relative to the reference frame. Given these positions and orientations, computer **50** displays, on a

display unit **48**, the image of body cavity **28** acquired by fluoroscope **22**, with an icon representing catheter **26** superposed on the image in the true position and orientation of catheter **26** relative to body cavity **28**.

Because patient **24** may move, relative to platform **34**, during the medical procedure, patient **24** also is provided with a receiver **38** of electromagnetic radiation. Computer **50** computes, from the signals received from receiver **38** in response to the electromagnetic radiation transmitted by transmitter **30**, the position and orientation of the body of patient **24** relative to the reference frame. This is in addition to the computation, by computer **50**, from the signals received from receiver **40**, of the position and orientation of fluoroscope **22** relative to the reference frame, and in addition to the computation, by computer **50**, from the signals received from receiver **32**, of the position and orientation of catheter **26** relative to the reference frame. Computer **50** records the position and orientation of patient **24** when the image of body cavity **28** is acquired. If patient **24** does moves, computer **50** adjusts the joint display of the image and the catheter icon on display unit **48** to reflect the movement of patient **24**, so that the catheter icon always is displayed in a manner that reflects the true position and orientation of catheter **26** relative to body cavity **28**.

As alternatives to receivers **32** and **44**, catheter **26** and patient **24** are provided with respective imageable markers **46** and **44**. Computer **50** locates the shadows of markers **46** and **44** in the image, using standard image processing techniques, and computes, from the positions of these shadows, the positions and orientations of catheter **26** and patient **24**.

A supplementary imaging device **52**, equipped with a receiver **40a** of electromagnetic radiation, also is provided, to acquire a supplementary image of a portion of the body of patient **24** that overlaps with the portion of the body of patient **24** that is acquired using fluoroscope **22**. Computer **50** computes, from the signals received from receiver **40a** in response to the electromagnetic radiation transmitted by transmitter **30**, the position and orientation of imaging device **52** relative to the reference frame. Computer **50** then displays the supplementary image, on display unit **48**, superposed on the image acquired by fluoroscope **22**, so that a point-of-interest, towards which catheter **26** is to be navigated, can be picked on display unit **48**, even prior to the introduction of catheter **26** into body cavity **28**. Improved methods of

effecting this superposition are taught by Gilboa et al. in WO 01/12057. Because computer **50** tracks the movement of both patient **24** and catheter **26**, an icon representing the point-of-interest is displayed on display unit **48** in a manner that represents the true position of the point-of-interest in body cavity **28**, so that catheter **26** can be navigated to the point-of-interest with reference to the relative positions, as displayed by display unit **48**, of the icon representing catheter **26** and of the icon representing the point-of-interest. Typically, supplementary imaging device **52** is an ultrasound probe, and the supplementary image is a two-dimensional ultrasound image.

Often, however, the images are not acquired interactively. Instead, the images are acquired by an operator of an imaging device, and the medical procedure is performed at a later time by another person, a physician, who was not present during the acquisition of the images. In such a case, either the images are acquired from a standard view, or text is added to the images to explain the acquisition orientation of the images. Even with such textual explanations, it often is not easy for the physician to visualize mentally the portion of the body that is described in any particular image. Furthermore, because the textual information is based on the operator's subjective impression of the acquisition orientation, the textual information may not be sufficiently accurate for the physician's use.

There is thus a widely recognized need for, and it would be highly advantageous to have, a method of acquiring and archiving medical images, such as ultrasound images, to facilitate the comprehension and use of these images by a physician.

SUMMARY OF THE INVENTION

According to the present invention there is provided a method of archiving an image of a body of a patient, including the steps of: (a) simultaneously: (i) acquiring the image, using an imaging device that includes a first tracker for measuring a position and orientation of the imaging device relative to a frame of reference, and (ii) measuring the position and orientation of the imaging device relative to the frame of reference, using the first tracker; (b) providing an indication of a position and orientation of the body relative to the frame of reference when the image is acquired;

(c) inferring, from the measured position and orientation of the imaging device and from the indicated position and orientation of the body, a position and orientation of the imaging device relative to the body; and (d) operationally associating with the image an indication of the position and orientation of the imaging device relative to the body.

According to the present invention there is provided a system for archiving an image of a body of a patient, including: (a) an imaging device for acquiring the image; (b) a first tracker for measuring a position and an orientation of the imaging device relative to a frame of reference; (c) a memory for storing an indication of a position and orientation of the body relative to the frame of reference; and (d) a processor for: (i) inferring, from the measured position and orientation of the imaging device and from the indicated position and orientation of the body, a position and orientation of the imaging device relative to the body, and (ii) operationally associating with the image an indication of the position and orientation of the imaging device relative to the body.

Although the present invention is described herein with reference to medical applications, it should be understood that the scope of the present invention includes veterinary applications. Thus, the patient that constitutes the "workpiece" of the present invention may be either a person or an animal.

In the context of the present invention, an "image" is a dataset that represents a portion of the interior of the patient, and not a dataset that represents a portion of the exterior of the patient. Thus, for example, an ultrasound slice, a CT volume, and a MRI volume are examples of images, whereas a photograph of the patient is not considered an "image". The scope of the term "image" in the context of the present invention includes both visual representations of a portion of the interior of the patient and digital datasets from which such visual representations can be reconstructed by appropriate means. Certain representations of the exterior of the patient, specifically, datasets of coordinates of points on the surface of the patient's body, and other point coordinates obtained by interpolation, are considered herein to be "maps" of the surface of the patient's body.

The present invention is directed towards medical images that are to be stored after acquisition and retrieved at a later time for use in medical procedures. In the

context of the present invention, "archiving" such a medical image means formatting the image to facilitate that later use by a person such as a physician who was not present during the acquisition of the image.

According to the present invention, an imaging device such as ultrasound probe **52** is provided with a tracker such as receiver **40a**. A "tracker", in the present context, is a device that is used to determine the position and orientation of the imaging device relative to a frame of reference. For example, as discussed above, receiver **40a** is used to determine the position and orientation of ultrasound probe **52** relative to the frame of reference defined by transmitter **30**. Specifically, the tracker is used to measure the position and orientation of the imaging device relative to the frame of reference while the image is being acquired. An indication of the position and orientation of the patient's body relative to the frame of reference while the image is being acquired also is provided. The two positions and orientations are combined mathematically to yield the position and orientation of the imaging device relative to the patient's body. An appropriate indication of this position and orientation of the imaging device relative to the patient's body is included with the image to facilitate the image's subsequent use by a physician who was not present when the image was acquired.

Preferably, the imaging device is an ultrasound probe.

Preferably, the indication of the position and orientation of the imaging device relative to the patient's body is a visual indication. In the present context, a "visual" indication can be either a visible image or a dataset, such as a digital dataset, from which such a visible image can be reconstructed by appropriate means. Alternatively, the indication of the position and orientation of the imaging device relative to the patient's body is a textual indication. The advantage of the textual indication of the present invention over the textual indication of the prior art is that the textual indication of the present invention, being based on a direct measurement of the position and orientation that it purports to describe, is guaranteed to be sufficiently accurate for subsequent use.

As discussed above, it is an object of the present invention to facilitate the performance of a medical procedure with reference to the acquired image or images, subsequent to and independent of the acquisition of the images, and even in a separate

location from the location in which the images were acquired. To this end, the medical procedure is performed with reference to the indication of the position and orientation of the imaging device relative to the patient's body.

Preferably, the indication of the position and orientation of the patient's body relative to the frame of reference includes a map of at least a portion of the surface of the patient's body. Such a map typically is a collection of coordinates, in the frame of reference, of points on the surface of the patient's body. Preferably, such a map is provided by steps including digitizing at least three points on the surface of the patient's body. Preferably, this digitizing is effected using a stylus that includes its own tracker for measuring the position and orientation of the stylus relative to the frame of reference, so that the digitizing is relative to the frame of reference. In fact, the imaging device itself may be used as the stylus. To increase the accuracy of the map, the digitized points are supplemented by interpolating the coordinates of points between and among the digitized points.

The patient may move during this mapping procedure. Therefore, most preferably, yet another tracker is secured to the patient's body, and the position and orientation of the patient's body relative to the frame of reference are measured using this additional tracker. The coordinates of the digitized and interpolated points are updated in accordance with the measured movement of the patient to ensure the accuracy of the indications of the positions and orientations of the imaging device, relative to the patient's body, that are associated with images acquired subsequent to the movement of the patient.

A system of the present invention includes the imaging device, a first tracker for measuring the position and orientation of the imaging device relative to the frame of reference, a memory for storing an indication of the position and orientation of the patient's body relative to the frame of reference, and a display unit for displaying images acquired by the imaging device along with the associated indications of the position and orientation of the imaging device relative to the patient's body. Preferably, the imaging device is an ultrasound probe.

Preferably, the system also includes a stylus for digitizing points on the patient's body to provide at least a portion of the map. This stylus may be included in the imaging device.

Preferably, the system also includes a second tracker for measuring the position and orientation of the patient's body, in case the patient moves while the images are being acquired.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 illustrates a prior art system for intra-body navigation of a catheter within the body of a patient, with reference to images acquired by a fluoroscope and an ultrasound probe;

FIG. 2 is FIG. 1 modified to illustrate a system of the present invention;

FIGs. 3, 4, 5a and 5b are exemplary visual indications of positions and orientations of acquired ultrasound images.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of a medical imaging method and system which can be used to acquire images of the body of a patient in a form suitable for archiving. Specifically, the present invention can be used to facilitate the performance of a medical procedure with reference to images acquired prior to, and independently of, the medical procedure.

The principles and operation of archival medical imaging according to the present invention may be better understood with reference to the drawings and the accompanying description.

Referring again to the drawings, Figure 2 is Figure 1 modified to illustrate a system of the present invention. Fluoroscope **22**, receiver **40**, the associated wires **51**, and markers **44** and **46** have been removed. Reference numeral **52** now designates the sole imaging device, specifically, an ultrasound probe. As in Figure 1, reference numeral **40a** designates a receiver of electromagnetic radiation that is rigidly attached to probe **52** and that is used as a tracker to measure the position and orientation of probe **52** relative to the common frame of reference defined by transmitter **30**. Tracker **40a** and probe **52** are connected by their own wires **51** to computer **50**, just as fluoroscope **22** and receiver **32** are connected to computer **50** in Figure 1.

In the system illustrated in Figure 2, probe **52** also serves as a stylus that is used to digitize representative points on the surface of patient **24**, for the purpose of constructing a map of the portion of that surface that is relevant to displaying the images acquired using probe **52**. Because tracker **40a** is rigidly attached to probe **52**, the position and orientation of tracker **40a** relative to a reference point on the housing of probe **52**, such as a distal tip **56** of probe **52**, is known. Therefore, the coordinates of tip **56** in the common frame of reference can be inferred from the measured position and orientation of tracker **40a**. The coordinates of points on the surface of patient **24** are measured by touching tip **56** successively to those points while measuring the position and orientation of tracker **40a**. This process of measuring the coordinates of these surface points is termed herein "digitizing" these surface points. The digitized points are stored in a memory **54** that is operatively associated with computer **50**.

Alternatively, a separate stylus, such as the MicroScribe, available from Immersion Corp, San Jose CA, is used to digitize representative points on the surface of patient **24**. The MicroScribe is a mechanical stylus which must be positioned and oriented separately relative to the common frame of reference defined by transmitter **30**. For example, the MicroScribe may be positioned and oriented relative to the common frame of reference by digitizing three fiducial points on an object having a known, fixed position and orientation in the common frame of reference.

If the combination of probe **52** and tracker **40a** is used as the digitization stylus of the present invention, then the digitization stylus of the present invention is said to be included in probe **52**, in the sense that in addition to the physical structure of the housing of probe **52**, which housing then constitutes the body of the stylus, probe **52** also includes the hardware, such as one or more piezoelectric transducers and the associated electronics, that is used to acquire the ultrasound images that are the primary *raison d'être* of probe **52**.

The position and orientation of the body of patient **24** relative to the common frame of reference also is measured, using tracker **38**. In case patient **24** moves during the digitization process, the new position and orientation of the body of patient **24** relative to the common frame of reference is measured using tracker **38**, and the mathematical transformation that transforms the old measured position and

orientation of the body of patient **24** to the new position and orientation of the body of patient **24** is applied to the coordinates of the map points that were acquired prior to the movement of patient **24**, to keep the map internally consistent.

As noted above, the preferred indications of the position and orientation of probe **52** relative to the body of patient **24** are visual indications. To this end, sufficient points on the surface of patient **24** are digitized to enable the display of a map of the relevant portion of the surface in sufficient detail to indicate, to a physician, the position and orientation, relative to the body of patient **24**, of the images acquired using probe **52**.

The map having been acquired, the desired images of the body of patient **24** are acquired, using probe **52**. As each image is acquired, the corresponding position and orientation of probe **52** are measured using tracker **40a**, and the corresponding position and orientation of the body of patient **24** are measured using tracker **38**. These positions and orientations are stored along with the images in an archival image database in memory **54**.

Alternatively, instead of acquiring a surface map of patient **24**, a standard map is stored in memory **54**, and patient **24** is instructed to lie on platform **34** so that the standard map constitutes an approximate rendition of the position and orientation of the surface of the body of patient **24** relative to the frame of reference defined by transmitter **30**. Such a standard map is sufficiently accurate for archival purposes relative to some subsequent medical procedures.

At a later time, a physician who desires to perform a medical procedure on patient **24**, with reference to the archived images, uses computer **50** to retrieve those images, as needed, from memory **54** and to display those images on display unit **48**. Each displayed image is accompanied by a visual indication of the position and orientation of that image, as acquired, relative to the body of patient **24**. Display unit **48** may be a video monitor. Alternatively, display unit **48** may be a printer that generates hardcopies of the images along with the associated visual indications of the positions and orientations of the images relative to the body of patient **24**.

Figures 3-5b are examples of visual indications of positions and orientations of acquired ultrasound images.

Figure 3 shows a Cartesian coordinate system superposed on the head and torso of patient **24**. The corresponding ultrasound slice is in the (*x*,*z*) plane.

Figure 4 is similar to Figure 3, except that the x and y axes are represented as crosshairs, with the x axis represented by the horizontal crosshair and the y axis being represented by the vertical crosshair. The head and torso of patient **24** is represented from a viewpoint such that the x axis is horizontal, the y axis is vertical and the z axis is in-line with the viewpoint.

Figures 5a and 5b show front and side views, respectively, of the head and torso of patient **24**. Superposed on these views of the head and torso of patient **24** are respective projections of ultrasound probe **52** and the location of the portion of the body of patient **24** that is imaged in the corresponding ultrasound slice **58**.

The heads and torsos shown in Figures 3-5b are most simply provided as parts of the alternative standard map of the body surface, as an interactively acquired map typically does not include this much of the surface of the body of patient **24**. Alternatively, both the standard map and the interactively acquired map are used, and the interactively acquired map is extrapolated by known digital fitting techniques, with reference to the standard map, to include the desired portions of the body of patient **24** that were not digitized. Note that to achieve a visually realistic rendition of a digitized map, the rendition must include interpolated points as well as the explicitly digitized points. This interpolation is effected by computer **50** using known techniques such as spline fitting.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

WHAT IS CLAIMED IS:

1. A method of archiving an image of a body of a patient, comprising the steps of:

(a) simultaneously:

(i) acquiring the image, using an imaging device that includes a first tracker for measuring a position and orientation of said imaging device relative to a frame of reference, and

(ii) measuring said position and orientation of said imaging device relative to said frame of reference, using said first tracker;

(b) providing an indication of a position and orientation of the body relative to said frame of reference when the image is acquired;

(c) inferring, from said measured position and orientation of said imaging device and from said indicated position and orientation of the body, a position and orientation of the imaging device relative to the body; and

(d) operationally associating with the image an indication of said position and orientation of the imaging device relative to the body.

2. The method of claim 1, wherein said imaging device is an ultrasound probe.

3. The method of claim 1, wherein said indication of said position and orientation of the imaging device relative to the body is a textual indication.

4. The method of claim 1, wherein said indication of said position and orientation of the imaging device relative to the body is a visual indication.

5. The method of claim 1, wherein said acquiring of the image is effected at a first location, the method further comprising the step of:

(e) performing a medical procedure, at a second location, different from said first location, with reference to said indication of said position and orientation of the imaging device relative to the body.

6. The method of claim 1, wherein said providing of said indication of said position and orientation of the body relative to said frame of reference is effected by steps including:

(i) providing a map of at least a portion of a surface of the body.

7. The method of claim 6, wherein said providing of said map is effected by steps including:

(A) digitizing at least three points on said surface.

8. The method of claim 7, wherein said digitizing is effected using said imaging device as a stylus.

9. The method of claim 7, wherein said providing of said map is effected by steps further including:

(B) interpolating said at least three digitized points.

10. The method of claim 6, wherein said map is relative to said frame of reference.

11. The method of claim 6, wherein said providing of said indication of said position and orientation of the body relative to said frame of reference is effected by steps further including:

(ii) measuring a position and an orientation of the body relative to said frame of reference; and

(iii) modifying said map in accordance with said measured position and orientation of the body.

12. The method of claim 11, wherein said measuring of said position and orientation of the body is effected using a second tracker secured to the body.

13. A system for archiving an image of a body of a patient, comprising:

(a) an imaging device for acquiring the image;

(b) a first tracker for measuring a position and an orientation of said imaging device relative to a frame of reference;

(c) a memory for storing an indication of a position and orientation of the body relative to said frame of reference; and

(d) a processor for:

(i) inferring, from said measured position and orientation of said imaging device and from said indicated position and orientation of the body, a position and orientation of the imaging device relative to the body, and

(ii) operationally associating with the image an indication of said position and orientation of the imaging device relative to the body.

14. The system of claim 13, further comprising:

(e) a display unit for displaying the image along with said indication of said position and orientation of the imaging device relative to the body.

15. The system of claim 13, wherein said imaging device is an ultrasound probe.

16. The system of claim 13, wherein said indication of said position and orientation of the body relative to said frame of reference includes a map of at least a portion of a surface of the body.

17. The system of claim 16, further comprising:

(e) a stylus for digitizing points on the body, said points then forming at least a portion of said map.

18. The system of claim 17, wherein said stylus is included in said imaging device.

19. The system of claim 13, further comprising:

(e) a second tracker for measuring a position and orientation of the body relative to said frame of reference.

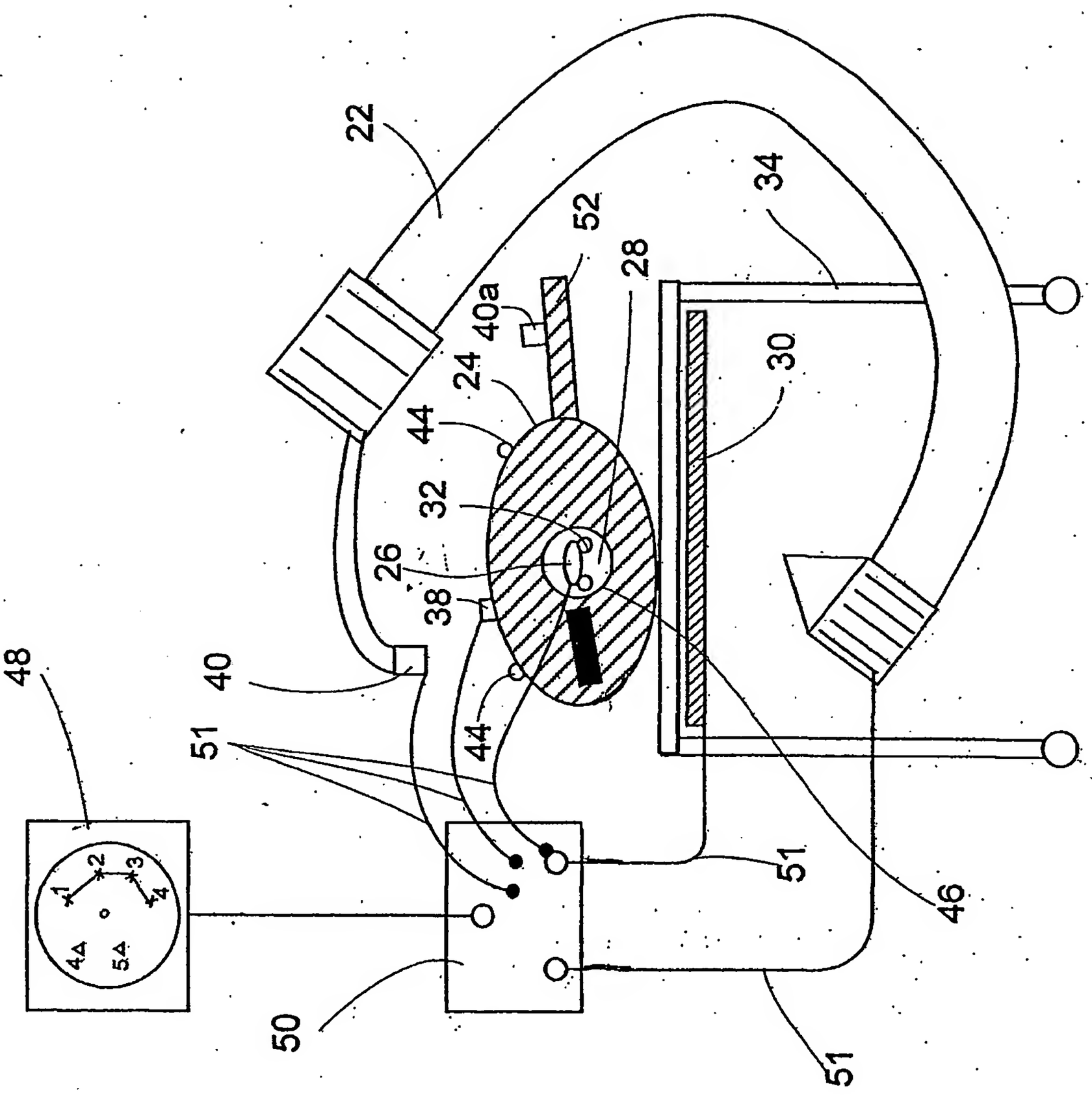

Fig. 1
(PRIOR ART)

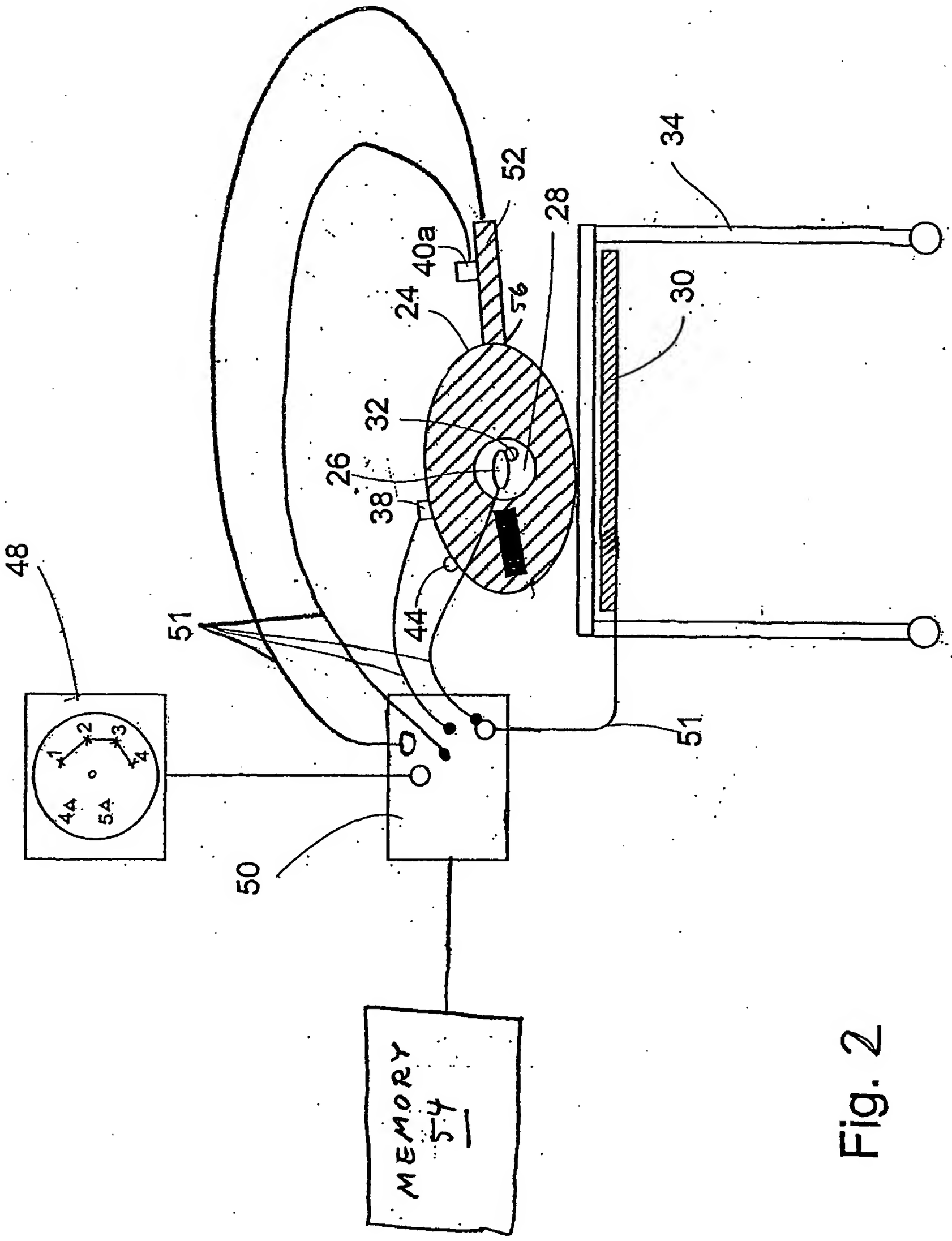

Fig. 2

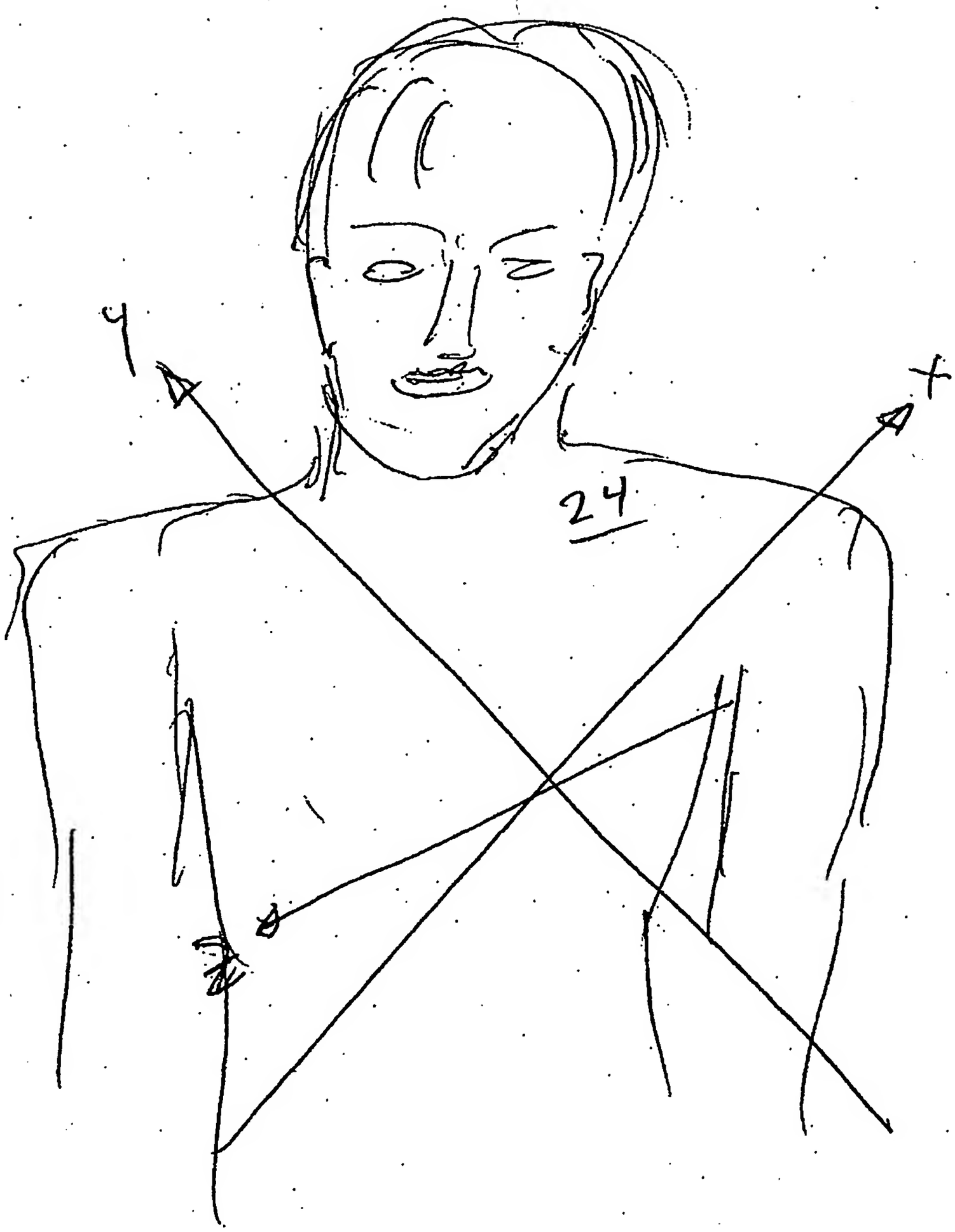

Figure 3

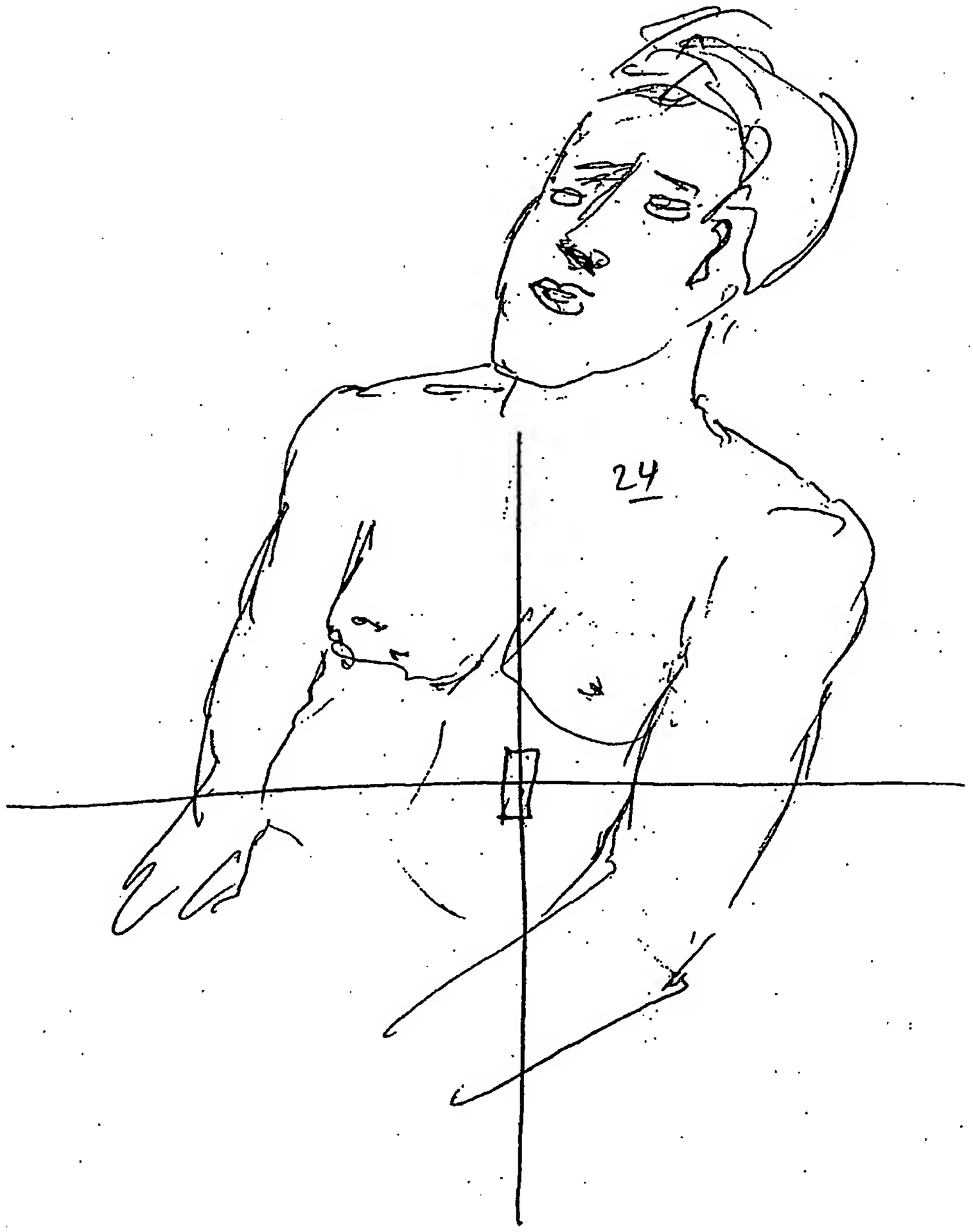

Figure 4

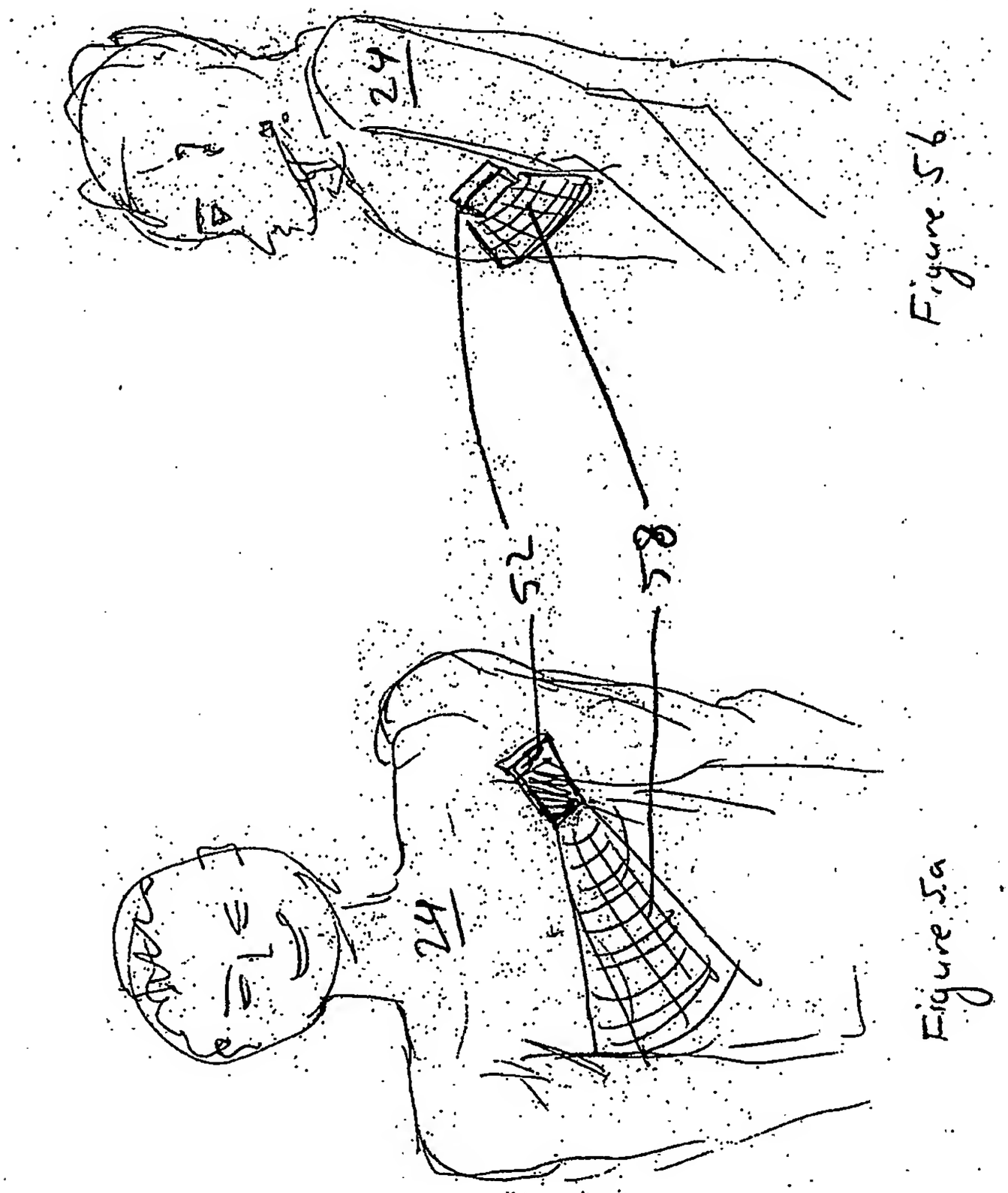

Figure 5a

Figure 5b